Technical Bulletin

NO. 9908

TOPIC: RESOLVING EXTERNAL MAGNETIC FIELD ERRORS Models LKP, CM, FM, or CXM Equipment

File TEC9908c (Replaces Technical Bulletin No. 727)

INTRODUCTION

The ability of DynAmp direct current measurement systems to operate accurately even in large external magnetic fields has long been established. The present trend to larger main bus currents and shorter bus lengths has resulted in increased probability of significant errors in low current indications of the presently manufactured LKP units or one of the older discontinued type CM, FM, or CXM units. Alternatively, smaller causes of these external magnetic fields can be earth's magnetic field, AC currents flowing nearby, or magnetized steel structures close to the measuring head. This may show up as a zero offset or, particularly at low bus current levels, an indication of a higher current than actually exists. This bulletin is meant to discuss such situations. The following subjects are covered:

I. Effects of external magnetic fields on measurement accuracy
   A. Normal operating point
   B. Low current measurements

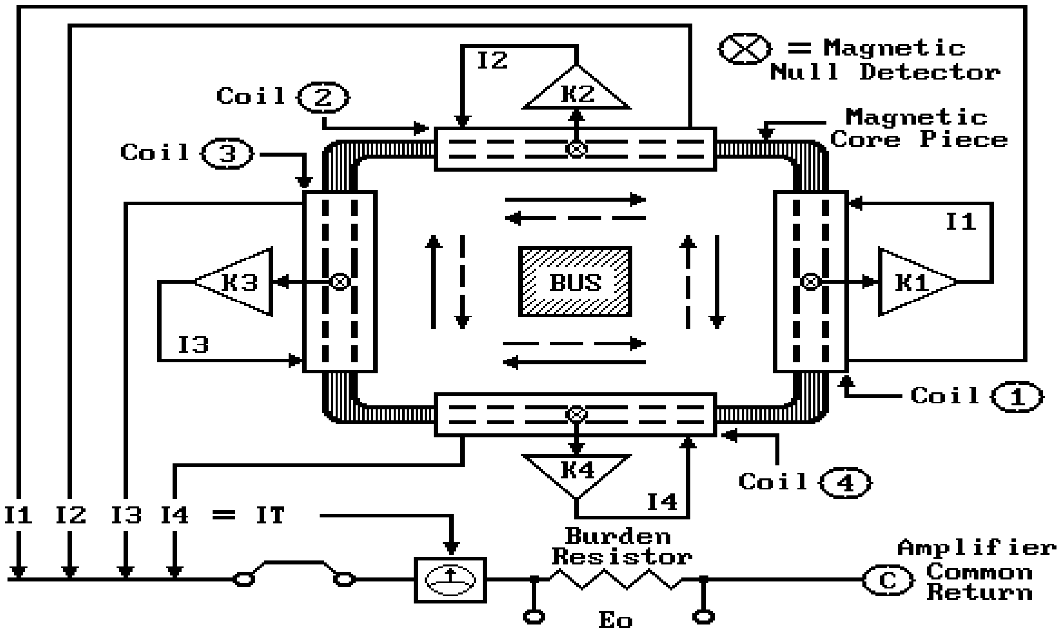
II. Analyzing a specific installation to determine the magnitude of these effects
   A. Proposed installation to determine the magnitude of these effects
   B. Determining the magnitude of the problem in operating systems

III. Discussion of solutions

IV. Summary comparison of solutions

I. EFFECTS OF EXTERNAL MAGNETIC FIELDS ON MEASUREMENT ACCURACY

A. The following description explains how a DynAmp dc metering system normally works:



CURRENT MEASUREMENT SYSTEM

1. Current in the primary bus sets up a magnetic field (dotted arrow), which causes a flux in the measuring head core piece.

2. When a flux is present, the magnetic null detectors (X) generate a signal to drive the high gain current amplifiers (K_1, K_2, K_3, and K_4).

3. The dc current from each amplifier passes through coils wrapped around the core and sets up a field "equal and opposite" (solid arrow) to the bus current field.

4. Each detector - amplifier - coil combination acts as an independent current feedback system to maintain a condition of "zero flux" around the core piece path.

5. The sum of the amplifier currents (I_1, I_2, I_3, and I_4) is directly related to the primary bus current. The ratio of current in the bus to output current (I_t) is 5,000:1.

6. Moving the measuring head with respect to the bus causes the relative values of I_1, I_2, I_3, and I_4 to change. The total current, I_t, however, remains constant.

7. External magnetic fields are self-canceling around the measuring head loop. An external field will cause one current to increase with a corresponding decrease in the other channel circuits. I_t remains proportional to only the primary bus current.

8. Burden resistors, in series with I_t, can be inserted to develop a signal output voltage. The channel voltages automatically adjust to maintain the proper channel currents. I_t remains unaffected.

9. The closed-loop design dynamically corrects for changes in line voltage, component aging, and ambient temperature variations.

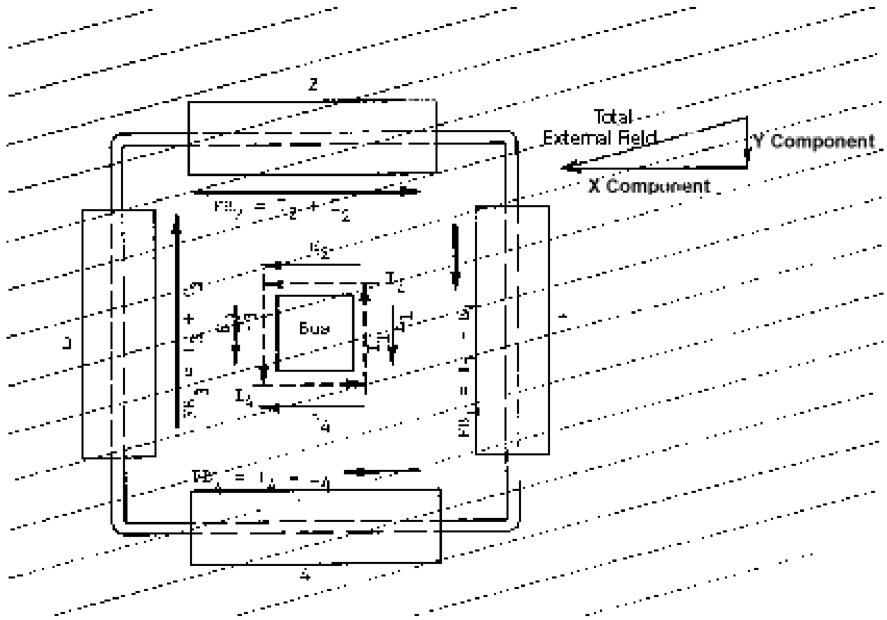
The functional diagram is a simplified analysis tool that helps us understand normal operation. To better understand the effects of an external magnetic field, we should separate the total field into three vector components for each channel.

<u>Component</u> <u>Description</u>

E. EXTERNAL The external magnetic field is the resultant in-line component of the magnetic field vectors due to all currents in nearby conductors. We can generally think of the total vector of the external magnetic field as reasonably uniform across the space the measuring head occupies.

I. INTERNAL The in-line component of the magnetic field vector due to the current flowing in the primary bus on which the measuring head is installed.

FB. FEEDBACK The magnetic field generated by the feedback current to null out the total of E and I.

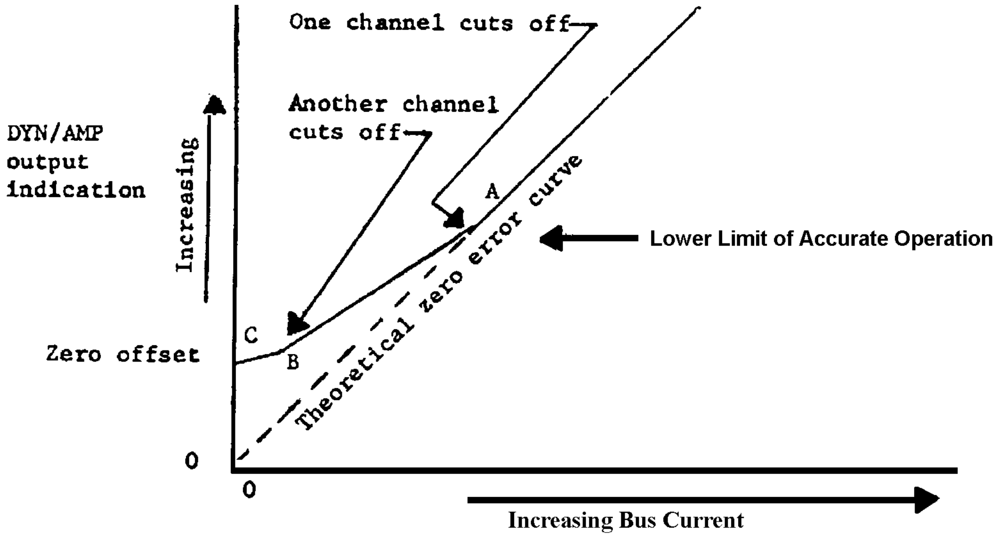


EXTERNAL MAGNETIC FIELD EFFECTS

If there were no external magnetic fields ($E_1 = E_2 = E_3 = E_4 = 0$), we would expect the feedback currents from each amplifier to be about equal. The net effect of the external field is a vector, which is additive on one side and subtractive on other sides of the measuring head. At the normal operating point, there is no problem; the additive and subtractive vectors cancel out around the loop of the measuring head. There may be a significant shift in the heat load caused by this external magnetic field. Channel 2 in diagram above is a good example where both the E and I magnetic fields are additive, causing one side to run much hotter than the other. However, all channels are operating in their normal dynamic range, so total cancellation takes place and the system is accurate.

B. Low current measurements

Now consider what happens as the internal bus current reduces to zero. The "I" vectors shrink to zero, leaving only the external magnetic field vectors to consider. As this happens, the feedback currents, and consequently the FB field vector, will decrease. Indeed, at some value of bus current, in channel 1 and in channel 4, the direction of the net input magnetic field will reverse. This reversal of the net input field direction is the condition (shown as point A in “Low End Errors” diagram) below which types LKP, CM, FM, CXM systems have errors, because their uni-directional amplifiers cannot force feedback current in the reversed direction to null out the field on this side of the measuring head.



LOW END ERRORS

The error will increase, somewhat linearly, below this point. There are break points in the curve as other channels cut off. The error will be maximum at zero bus current. <u>Please note that the system is accurate for bus currents above point A</u>.

When is the zero offset likely to be a problem?

1. When the affected system is one of several that are totalized and the totalized signal is used for control. This may be a particularly significant problem if the rectifier is to be shut down for a long time.

2. If the totalized current signal is used for ampere hour measurement, the zero offset will affect this data.

When is the zero offset not likely to be a problem?

1. When the external magnetic fields are much weaker than the internal bus field. Therefore, this problem is unlikely to occur on main bus measurements.

2. When bi-directional DynAmp models are used, such as LKB, LKAT or LKCO.

3. When accuracy at low currents is not needed.

II. Analyzing specific installations to determine the magnitude of these effects

A. Proposed installations

DynAmp engineers can predict the approximate magnitude of the offset through the use of a digital computer analysis program. This requires full knowledge of the active bus structures within 30 feet / 10 meters of the proposed measuring head location.

B. Determining the magnitude of the problem in operating systems

If the answers to the following questions are all "yes", then external magnetic fields are a probable mode of error.

1. Determine if the DynAmp is reading too high at low bus currents, e.g. if the dc disconnect switch is open, yet the DynAmp still indicates a current flow (zero offset effect).

2. Under condition 1, measure the channel voltages. Determine if one or two channels have several volts across them and another one or two are reading zero volts.

3. Determine if the DynAmp appears to be operating properly near the normal full-scale rectifier current (all channel voltages over 3 volts).

4. Determine if there are other active buses in the area.

III. Possible solutions

First, rest assured that there is a solution to the situation. The only consideration is what has to be done to accomplish a satisfactory solution.

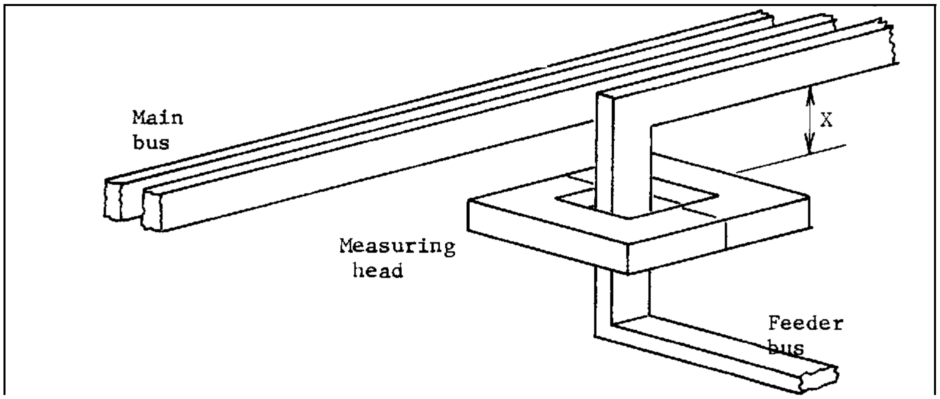
Initially the customer should consider if anything really needs to be done. What is the real significance in this case? Is this a mode of operation that is frequent? How many hours per week, month, and year are likely to be logged in this mode? What will be the magnitude of error in the worst case? What effect will this error have? If the effects are serious, then something must be done, but if the effects are trivial, and if the solution is expensive, then perhaps it is best to recognize the possibilities but not change anything.

It is usually possible to eliminate the error. It is also possible, and probably a more economic, to minimize the effects to an insignificant level. Following are solutions:

Change the measuring head location or orientation

It may be possible to reduce the break points where the measuring head errors start to very low levels by putting the reversed channel close to the internal bus. This may cause over-temperature conditions when the measured bus current is very high, so be sure to check by making channel voltage measurements.

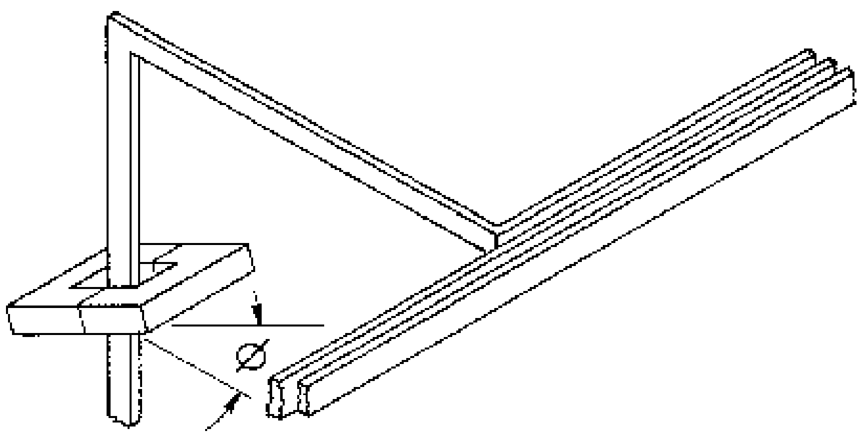
Often the measuring head is located near a 90° turn in the bus. Sometimes putting the measuring head beyond the elbow will help solve the problem.



THE SEVERITY OF THE EXTERNAL MAGNETIC FIELD
WILL REDUCE AS THE DIMENSION "X" INCREASES.

It might be possible to tilt the head so that the external magnetic field does not have a component in line with either major core direction. This usually occurs when the extension of the plane of the measuring head intersects the center line of the main bus.

Turning the measuring head only has the effect of shifting which channels are affected by the external field. This may be useful to minimize the hot spot temperature, by sharing the load between channels, and it may decrease the zero offset.



PLANE OF MEASURING HEAD INTERSECTS THE BUS
GENERATING THE MAJOR EXTERNAL MAGNETIC FIELD.

Selection of an alternate location for the measuring head can probably best be accomplished through conferences with the DynAmp engineers. As mentioned in section II-A, it is possible to make some estimates of the zero offset through computer analysis of the plant bus structure.

AC shutdown

It is possible to temporarily eliminate the amount of zero offset by removing the ac power from the DynAmp when the rectifier is taken off the line. This simply prevents the turn-on of the channels that are magnetically forward biased by the external field. This may display an objectionable characteristic, however, when overcurrent relays are tied into the DynAmp output circuit, for when the DynAmp power is restored, a transient may occur in the metering system, which would trip out the breaker. AC shutdown may still be the best solution if the condition is likely to happen only very infrequently. This does nothing to reduce the errors at low bus currents.

Diode and relay contact

This is a solution which removes the zero offset signal at zero rectifier current. A relay contact shorts across the individual DynAmp output, when the rectifier is shut down, to shunt the output current, and a diode is put in to block this short from affecting the signal accuracy across the totalizing shunt. Typical connection schemes for LKP, CM, FM, and CXM systems are attached. This removes the secondary problem of the possibilities of excessive restart transients that were present in the ac shutdown option listed above.

Change the bus design

For proposed installations, this is a good technique to investigate. DynAmp engineers, with the aid of the computer analysis program, can suggest and evaluate these solutions.

Change the units to bi-directional models

DynAmp manufactures types of direct current measurement systems which are designed to remain accurate even when the magnetic field reverses.

The model LKAT will provide 0.75% accurate metering for rectifier applications and also provide reverse / overcurrent protection.

The model LKCO, based on optical technology will provide 0.1% accurate metering for bi-directional or uni-directional applications.

Both the LKAT and LKCO will provide accurate, reliable measurements regardless of external magnetic fields.

Comparison of techniques to reduce external magnetic field errors at low rectifier currents

Technique	*Good Features*	*Considerations*
Understand, but take no action	Lowest cost Explains the readings	Does not remove the error
Move the measuring head to a less stringent location	Low cost Can be complete cure	Not always possible or practical
Tilt the measuring head	Low cost Can be complete cure	Not always possible
Remove the ac from the DynAmp when the rectifier bus current is zero	Low cost Prevents zero offset errors	Does not resolve low current errors May trip over current relays as ac is restored
Use a diode & relay contacts to remove the zero offset	Low cost Prevents zero offset errors Avoids trip-out circumstances of ac removal	Does not resolve low current errors
Change the bus design	Can be a complete cure. Not difficult on proposed locations	Cost needs to be considered
Change some units to bi-directional ones	Will solve most problems Model LKAT Model LKCO	May require rescaling of control system